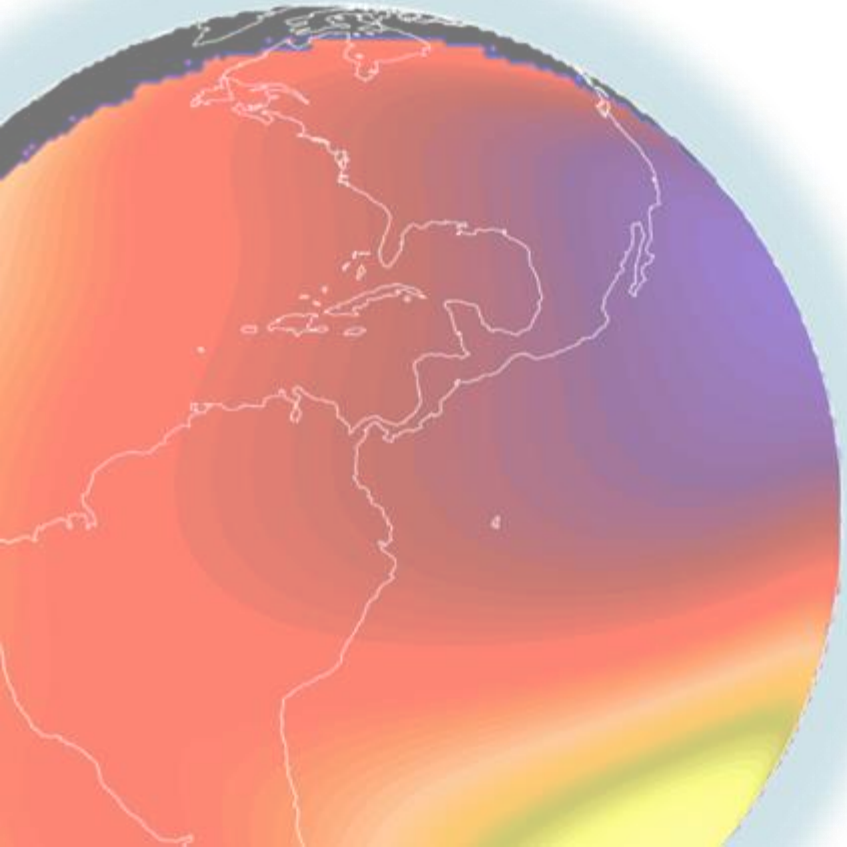
Imaging the Boundary Between Earth and Space – The Global-scale Observations of the Limb and Disk (GOLD) Mission



Richard Eastes (UCF/FSI)
GOLD Mission PI

William McClintock (CU/LASP)
GOLD Mission Deputy-PI

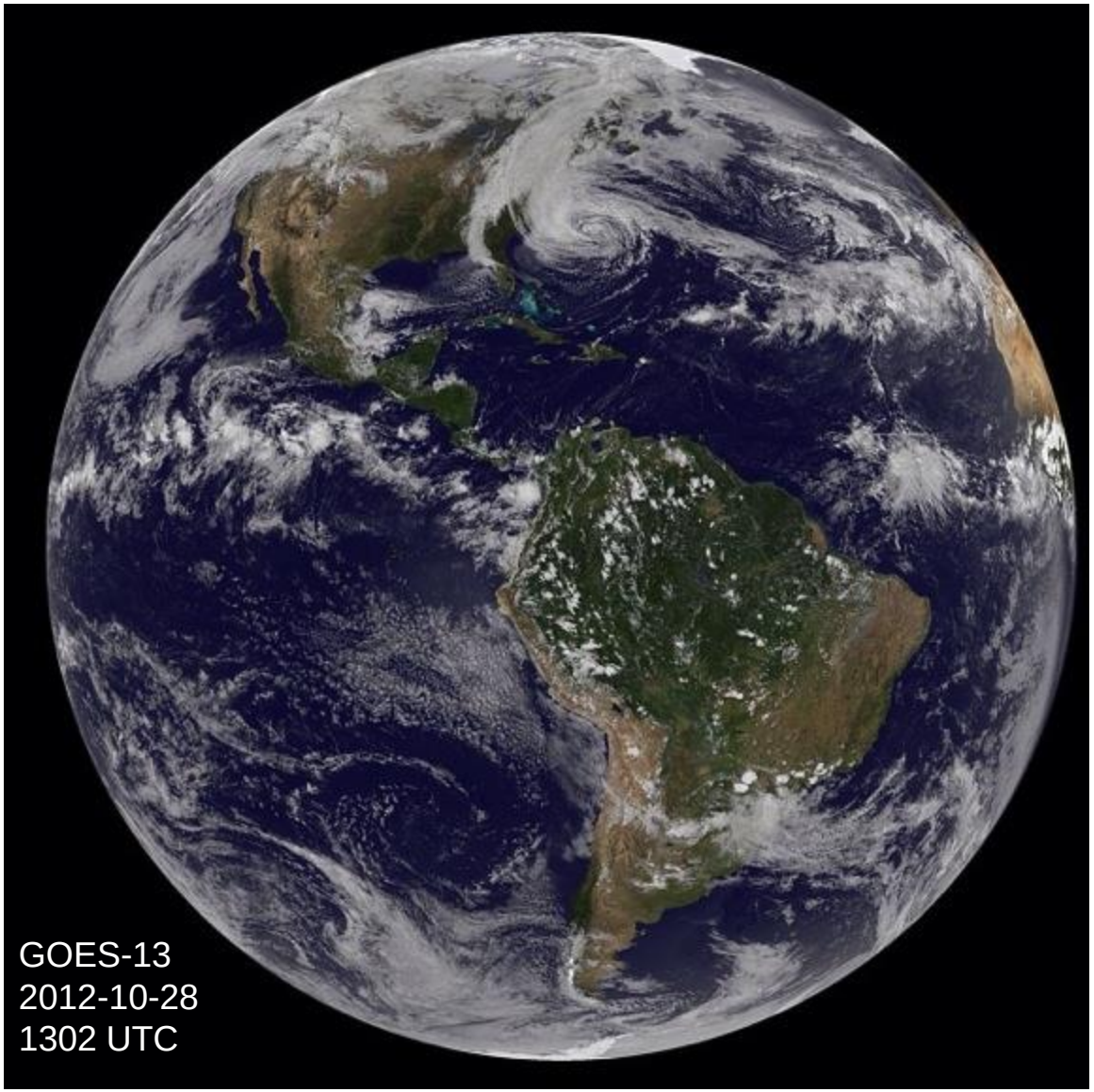
NASA UCF LASP SES Government Solutions

The View from Geostationary Orbit

GOLD will make unprecedented, near real-time images of upper atmosphere's response to forcing from above and below

GOLD images the disk and limb from geostationary orbit

Full disk images at 30-minute cadence

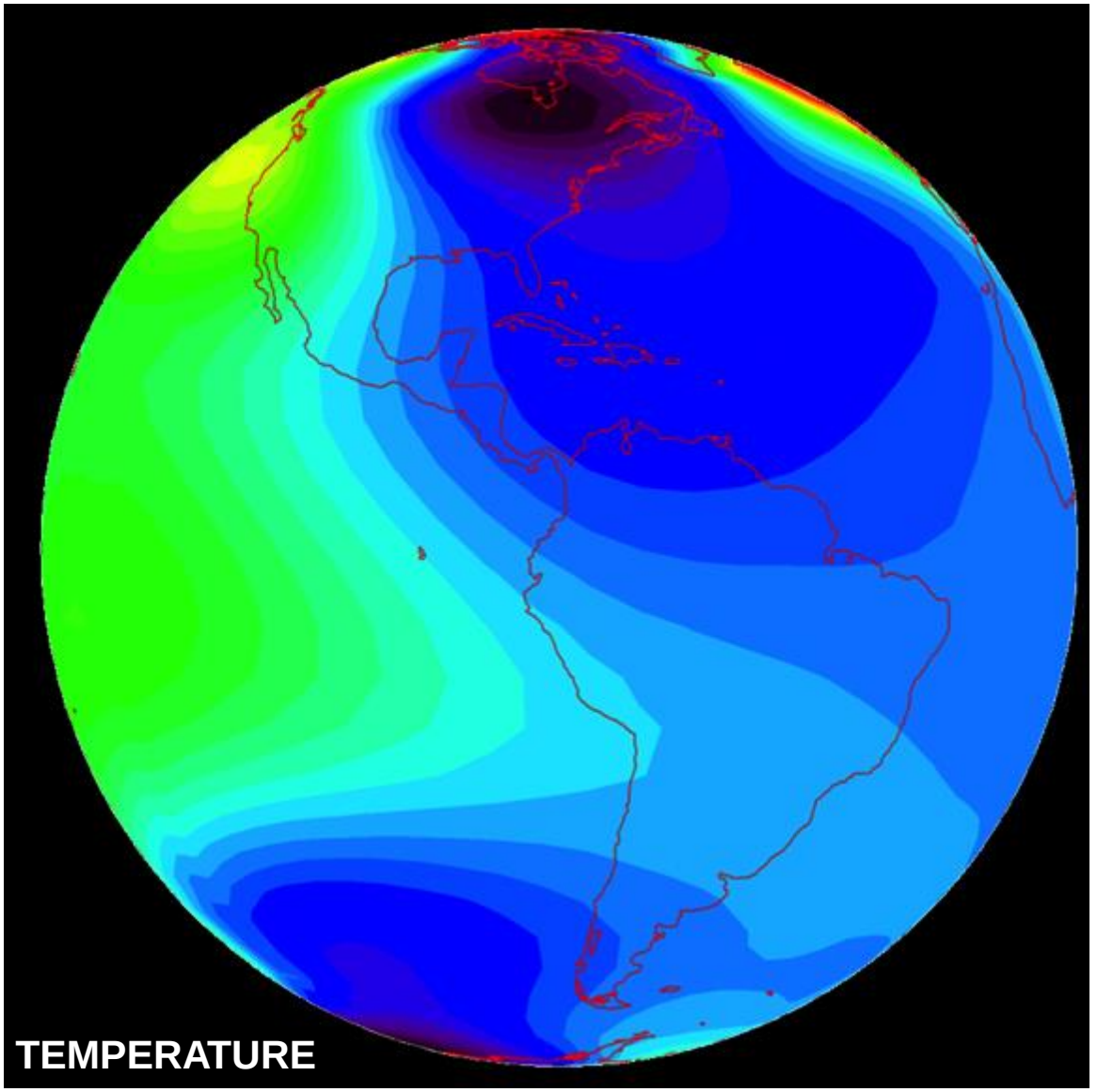


The View from Geostationary Orbit

GOLD images the disk and limb from geostationary orbit

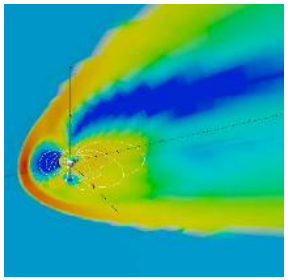
Full disk images at 30-minute cadence

GOLD measures the composition and temperature of the thermosphere

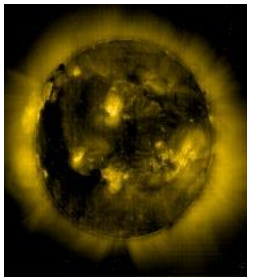


Weather in the Thermosphere-Ionosphere

Forcing from Above



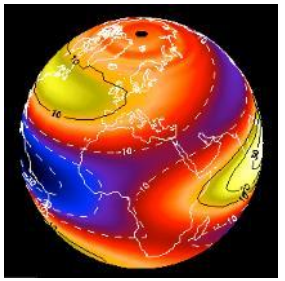
Science Question 1 (Q1). How do geomagnetic storms alter the temperature and composition structure of the thermosphere?



Q2. What is the global-scale response of the thermosphere to solar extreme-ultraviolet variability?

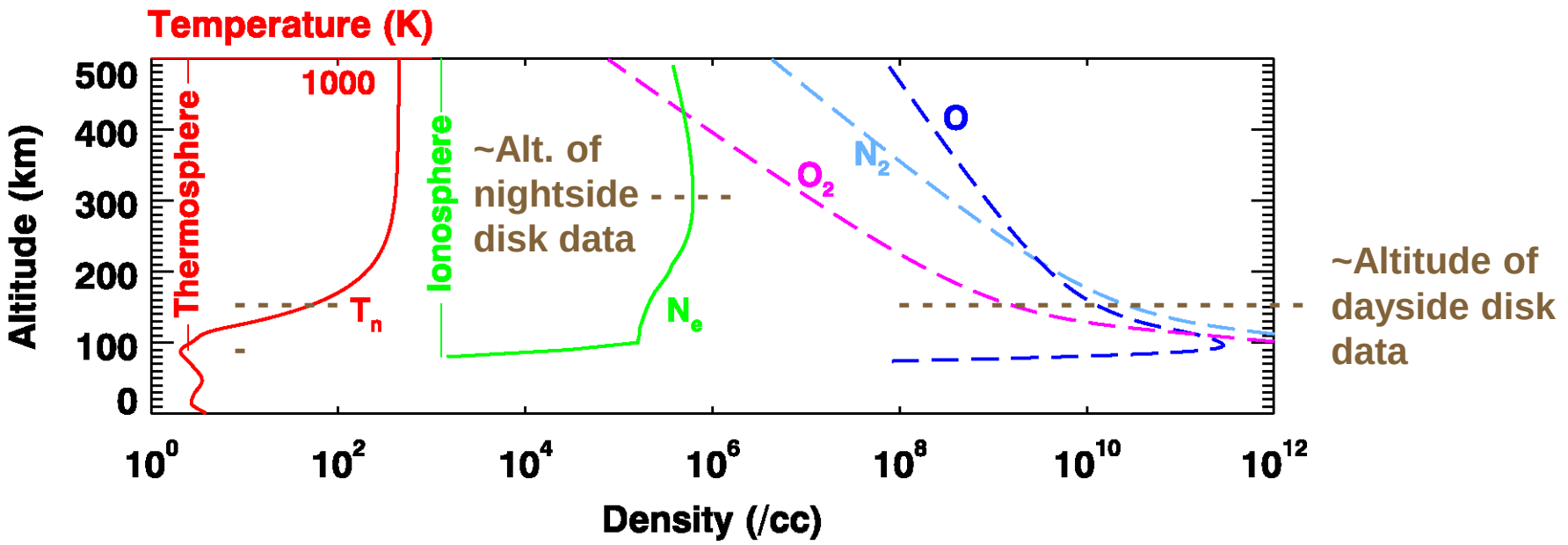
Q4. How does the nighttime equatorial ionosphere influence the formation and evolution of equatorial plasma density irregularities?

Q3. How significant are the effects of atmospheric waves and tides propagating from below on thermospheric temperature structure?



Forcing from Below

The Thermosphere-Ionosphere System



GOLD simultaneously images temperature and composition (O/N_2) in lower thermosphere, near 150 km, on the dayside disk

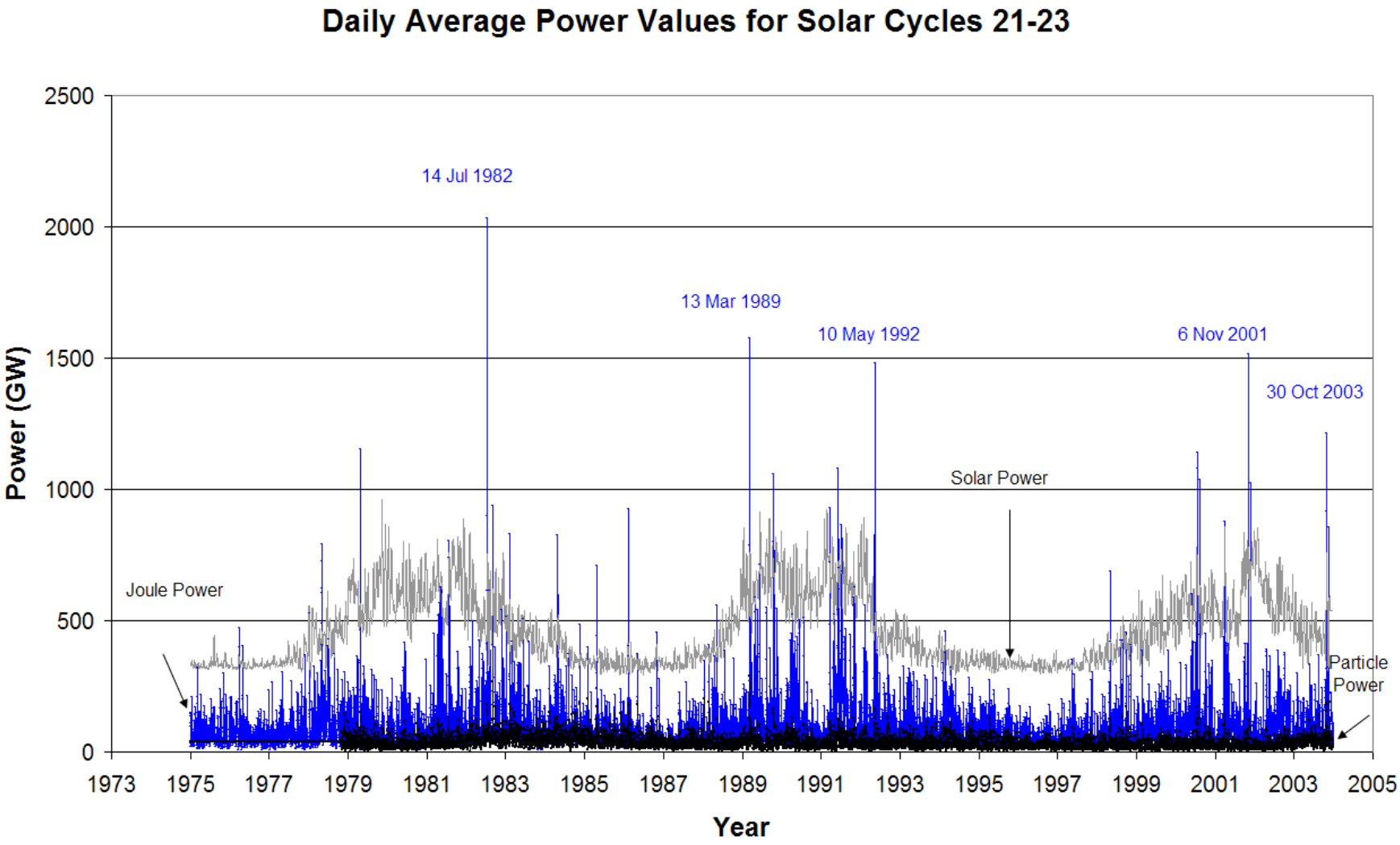
On nightside disk GOLD images of N_{max}, peak electron density

Baseline Science Requirements Traceable to Mission Science Objectives

Baseline Science Requirements	Question
1. GOLD shall make disk images of atomic oxygen (O) 135.6 nm emissions and molecular nitrogen (N_2) Lyman-Birge-Hopfield (LBH) emissions over a latitude range of ±60˚ and a longitude range of ±70˚ relative to spacecraft nadir.	Q1-Q4
2. GOLD shall construct, on the sunlit portion of the disk, images of: a. lower thermosphere temperature with a precision of 55 K with 60 minute cadence and spatial resolution of 250 km × 250 km (at nadir); and b. thermosphere column composition (O/N_2 radiance ratio) with a precision of 10% with 30 minute cadence and spatial resolution of 250 km × 250 km (at nadir).	Q1-Q3
3. GOLD shall construct, on the nighttime portion of the disk, images of Nmax F2, at the peak of the equatorial arcs, with a precision of 10% and a latitude resolution of 2˚.	Q4
4. GOLD shall track ionospheric bubbles (depletions) within a single equatorial arc with a precision of 20% in brightness and a spatial resolution (at nadir) of 100 km in the longitudinal direction.	Q4
5. GOLD shall measure near-equatorial limb profiles of the N_2 LBH emissions up to an altitude of approximately 350 km.	Q1-Q2
6. GOLD shall measure exospheric temperature (near-equatorial) with a precision of 40 K in the daytime.	Q1-Q2
7. GOLD shall measure O_2 line-of-sight column densities at an altitude of 160 km with a precision of 10% and a vertical resolution of 10 km in the nighttime and daytime by stellar occultation.	Q1-Q3
8. GOLD shall perform all of the above from geostationary orbit for two years.	Q1-Q4

Baseline mission unchanged since Proposal

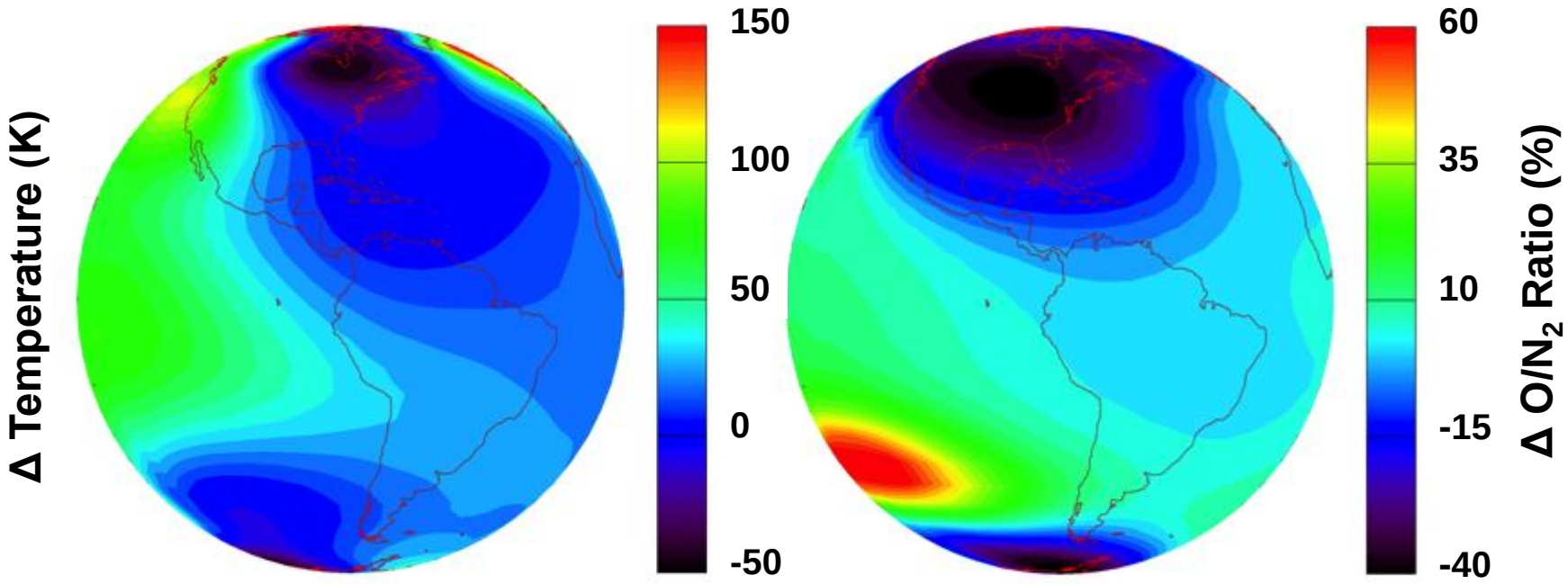
Forcing of the T-I System from Above



Knipp et al, 2004

Geomagnetic Forcing of T-I System

How do geomagnetic storms impact Earth's space environment?

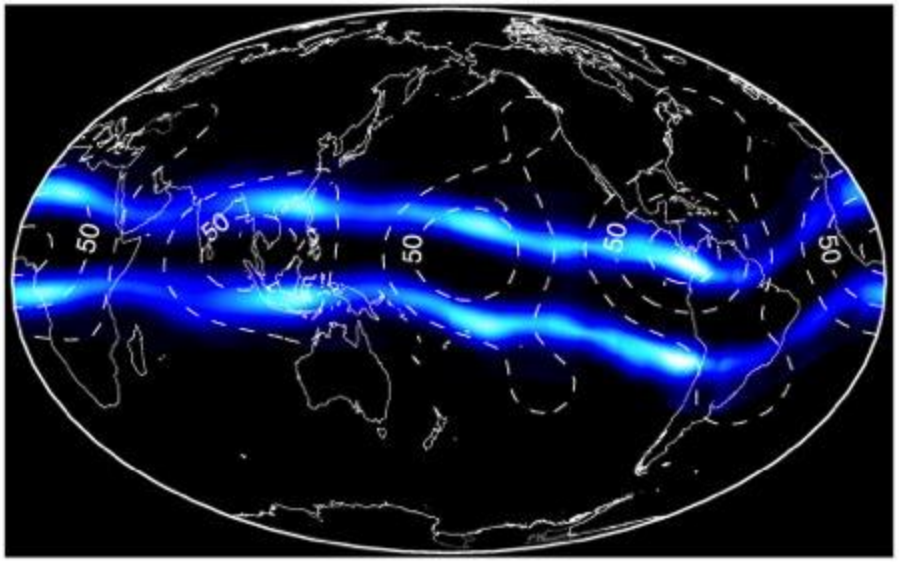


Modeled changes in upper atmosphere during storm

GOLD will discover how the upper atmosphere acts as a weather system

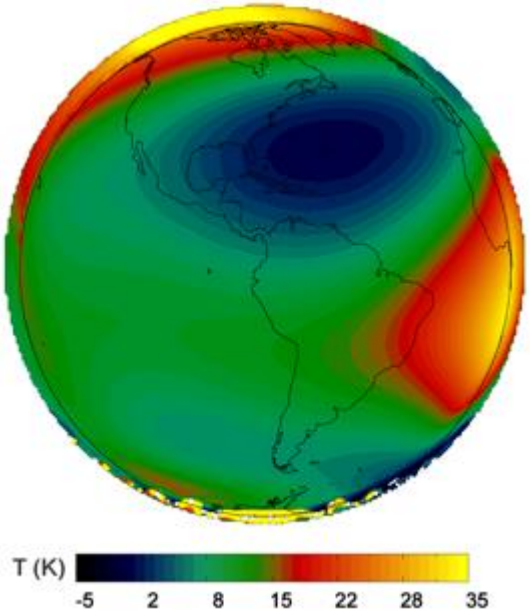
Forcing from Below

- **Nighttime: evidence that geographic-locked atmospheric tides affect the ionosphere**
- **Theory suggests tides cause 4 peaks in longitudinal morphology of the equatorial ionosphere**



Composite map of equatorial O^+ recombination emission from IMAGE far-ultraviolet observations at constant local time [*Immel et al.*, 2006]

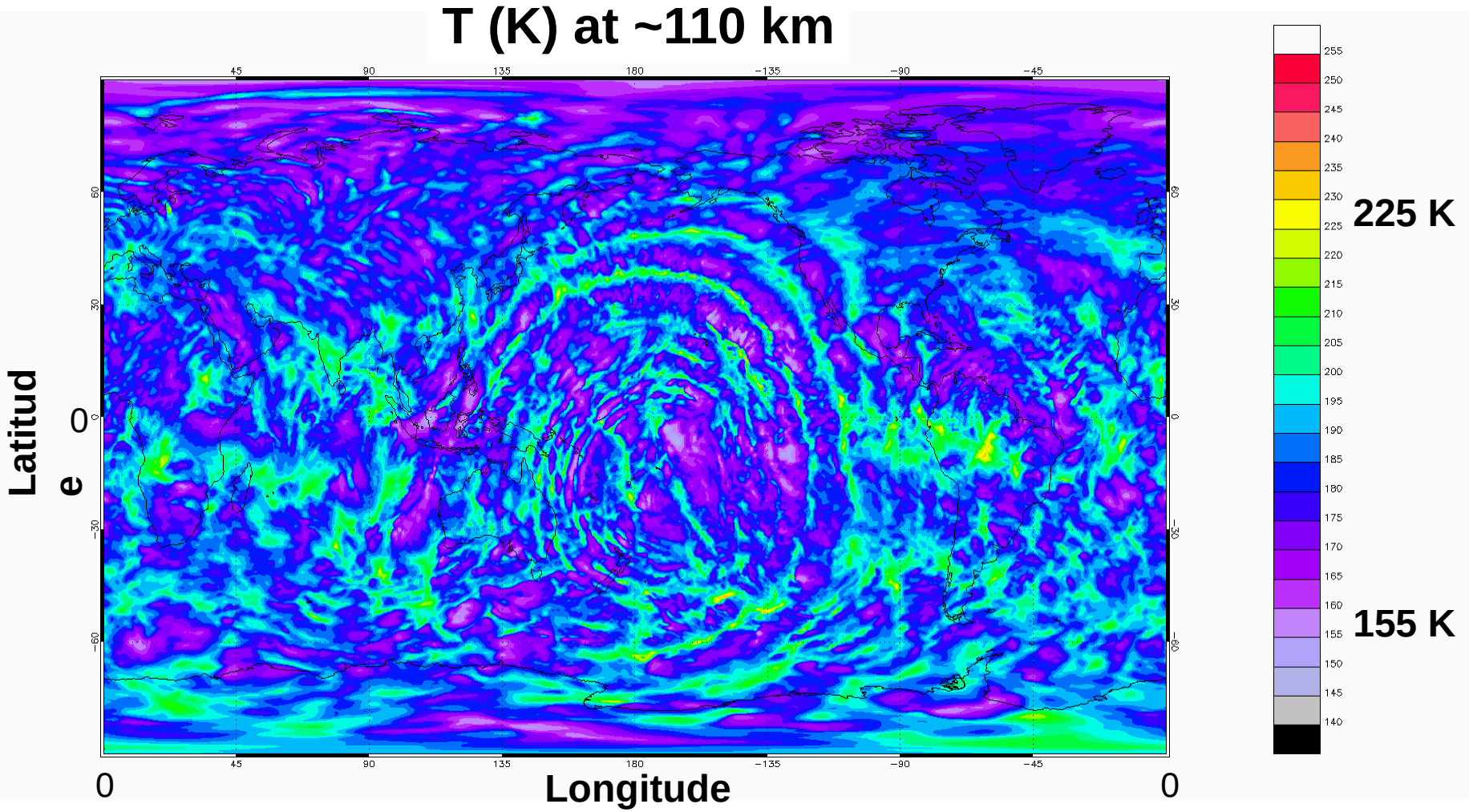
- **Daytime: observed thermospheric temperatures & densities consistent with tidal influences from lower atmosphere**
- **GOLD images temperatures at sufficient precision to observe tides**



Modeled ΔT(K) due to Tides

Temperature differences between simulated GOLD observations of thermosphere with and without tides

Forcing from Below During Typhoon



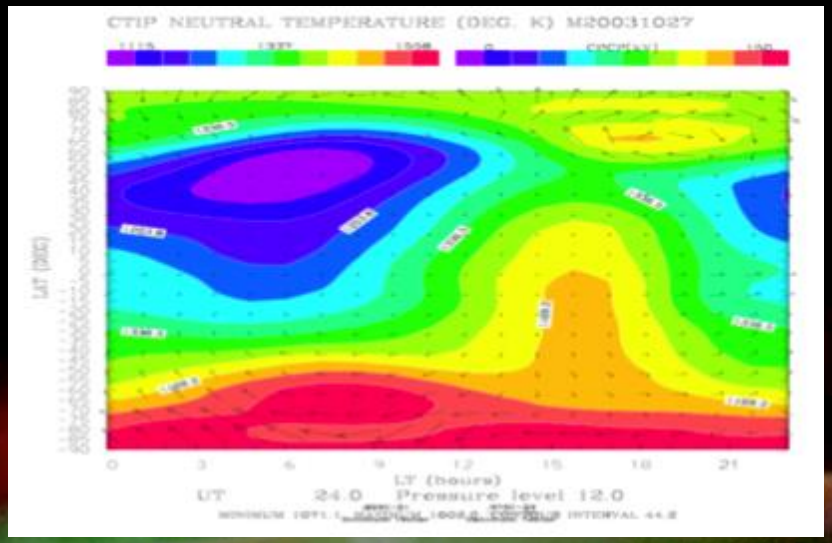
WACCM Calculation of Gravity Waves at High Resolution (0.25° Spatial by 0.1 Scale Height)

From: Hanli Liu at NCAR/HAO

With and Without Lower Atmosphere:

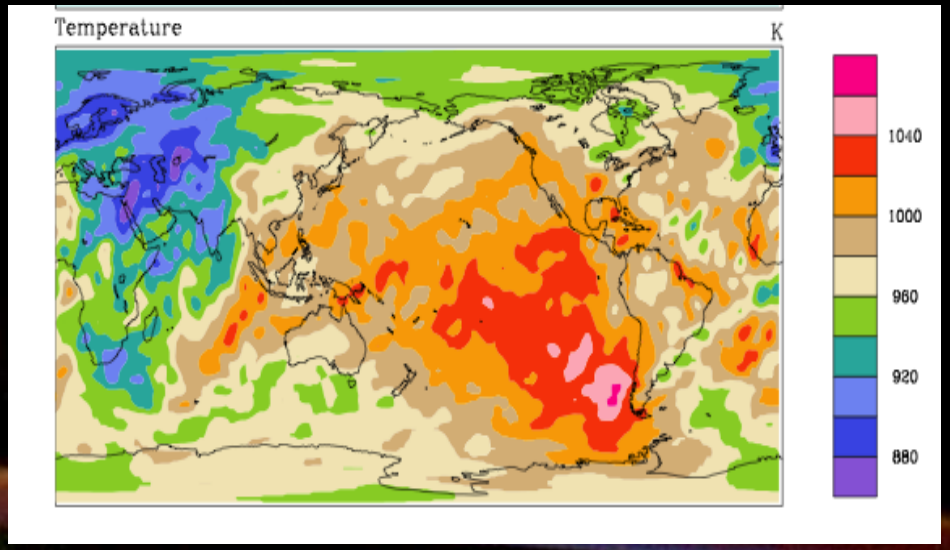
Typical iono-thermosphere model:

- **Driven by Solar EUV and Geomagnetic Storms.**
- **Global maps show little fine structure**



Ionosphere-thermosphere model coupled to the lower atmosphere: Global maps show structure relevant to

- **GPS accuracy and availability**
- **HF Comm.**



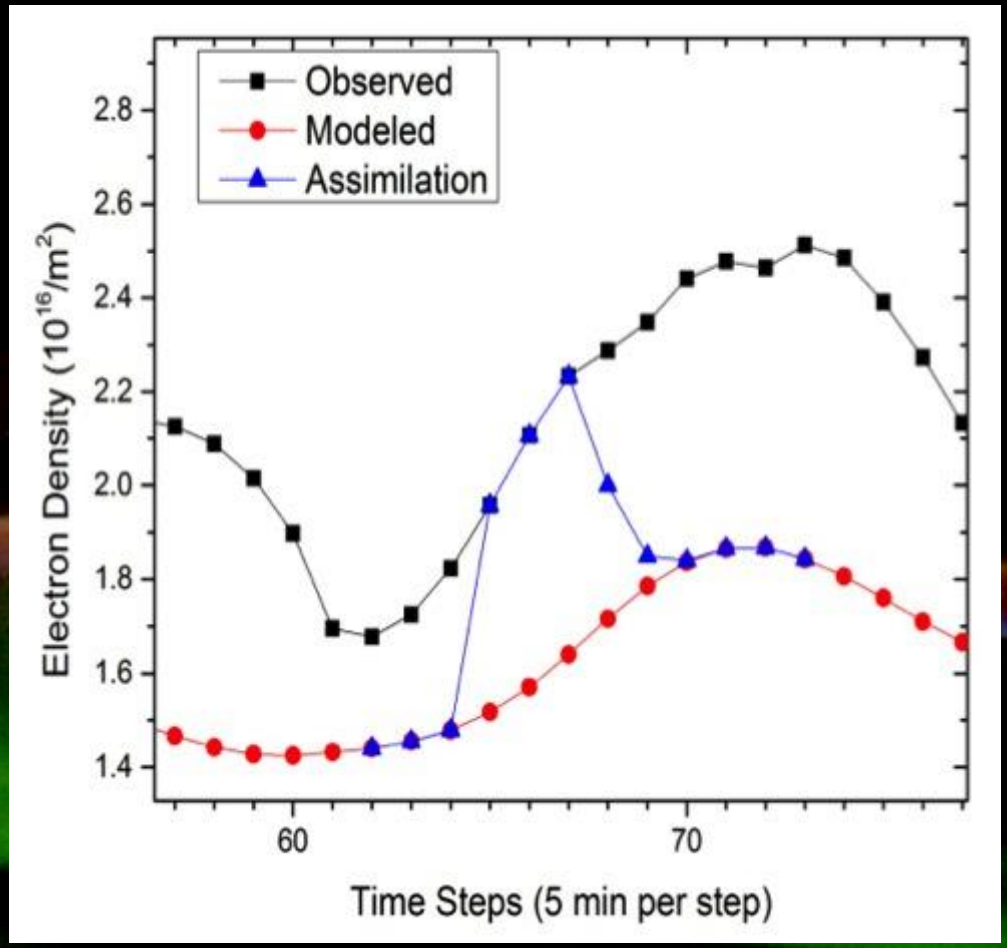
The temperature structure from a stand-alone thermosphere ionosphere plasmasphere model (e.g., CTIPe) is similar to the MSIS empirical model. The Whole Atmosphere Model (WAM) drives variability from the chaotic lower atmosphere which introduces a whole spectrum of variability.

R. Viereck/NOAA

Data Assimilation Challenge

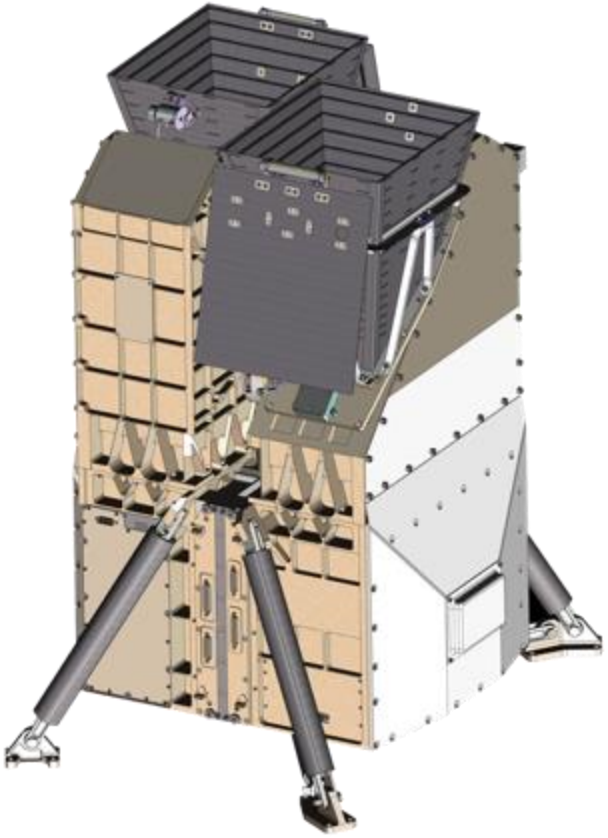
- The Ionosphere-Thermosphere system is a strongly driven system
  - Order of magnitude electron density changes…
    - Driven by order of magnitude changes in solar EUV and Geomagnetic activity.
    - Occur on timescales of minutes.

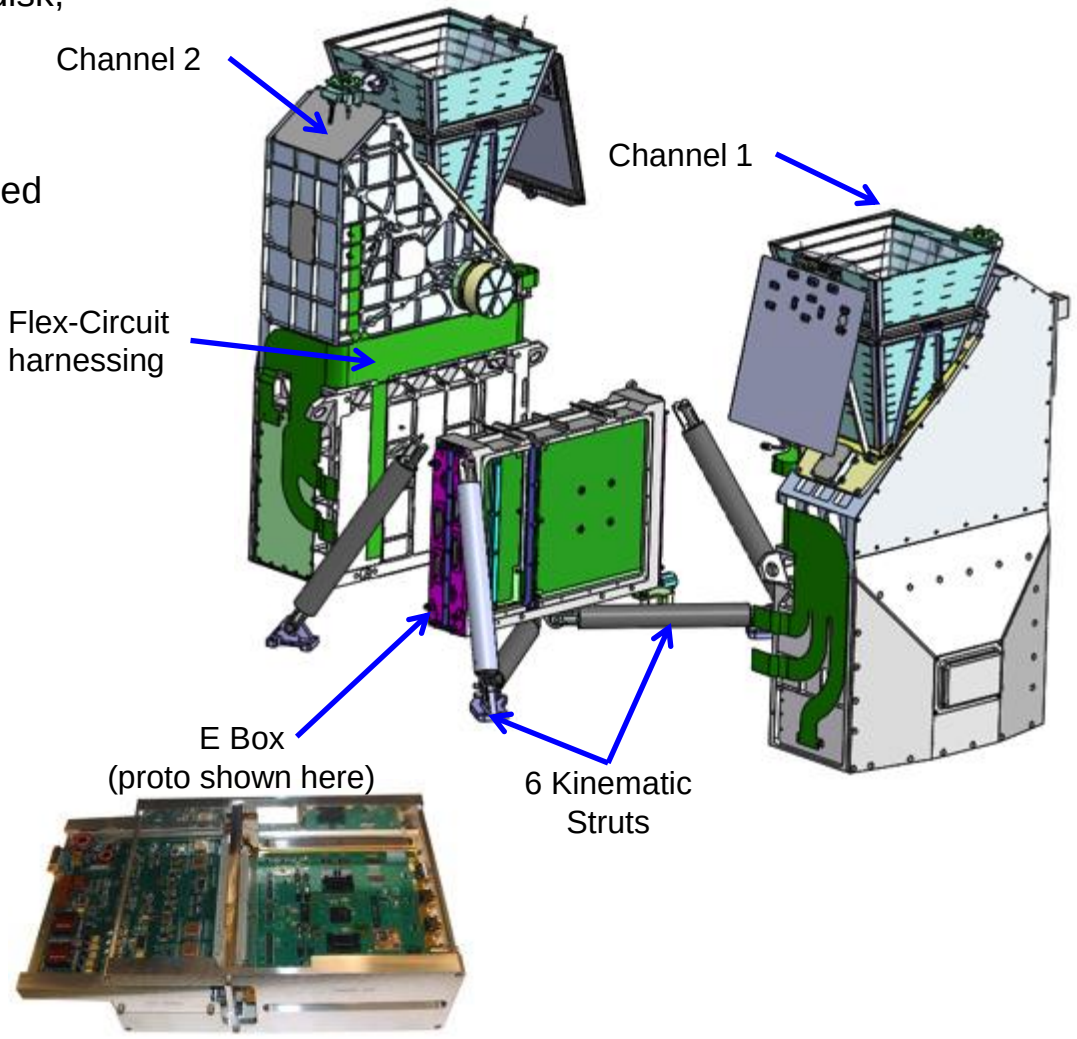
- Data assimilation is challenging
  - Adjusting ionospheric conditions to match observations does not work. The ionosphere returns to its original state in the next few time steps.
- Not sure which DA scheme is best
  a. Extended GSI/hybrid (3D EnVar)
  b. Extended 4D hybrid (4D EnVar)
  c. Separate Iono-Thermo ensemble Kalman Filter



GOLD Mission Instrument

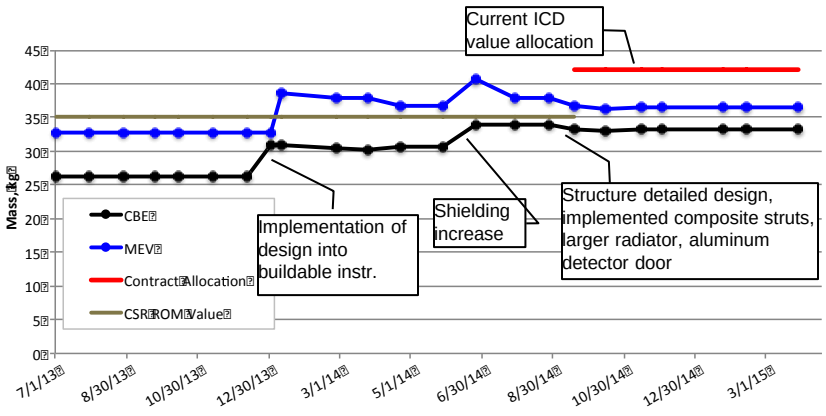
- Imaging Spectrograph: Two independent, identical channels imaging the limb and disk, and a single processor packaged in one housing
- Wavelength range: 132 – 160 nm
- Detectors: Microchannel plate, 2-D crossed delay line anode

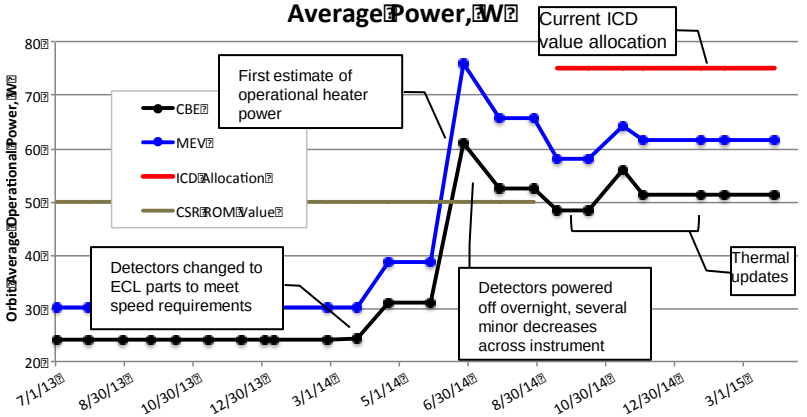




Resource Management

- Mass, Power and Data Rate
- Assuming transfer to geostationary orbit using electric propulsion





Resource	CBE	MEV	ICD Stated Value	Reserves		Margin against ICD Stated Value	
				Value	%	Value	%
Mass (Kg)	33.3	36.4	42.0	3.2	9.5%	5.5	15.2%
Power (24 hr avg.) (W)	51.3	61.6	75	10.3	20%	13.4	22%
Power (peak) (W)	87.8	105.4	109	17.6	20%	3.9	4%
Power (survival) (W)	28.7	34.4	50	5.74	20%	15.6	45%
Downlink Rate (Mbit/sec)	6	6	6	0	0%	0	0%

GOLD Project Leverages Team's Prior Flight Experience

Light Shade (MAVEN RS)

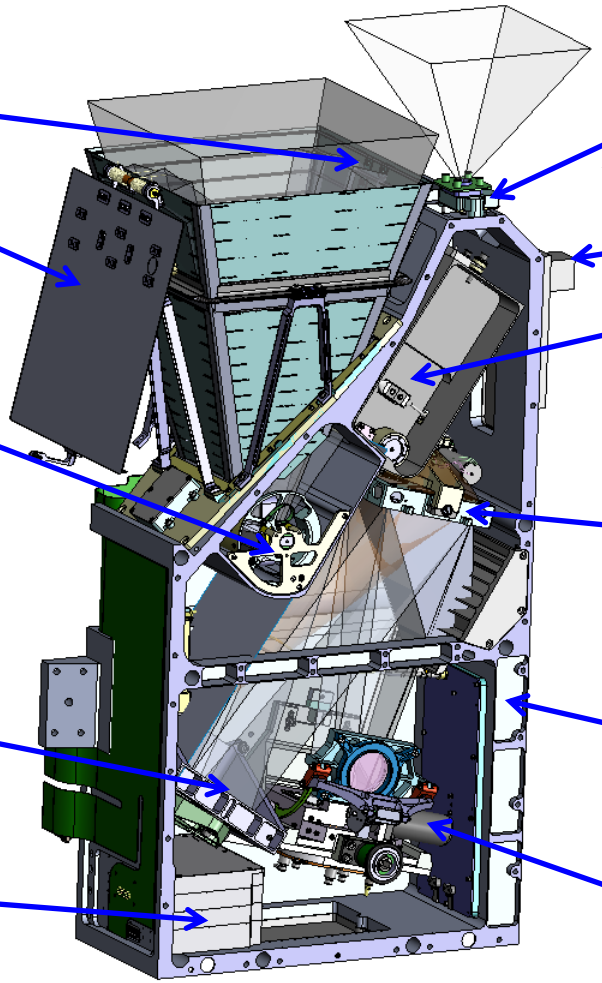
1-Shot Aperture Cover (LDEX, SDO EVE)

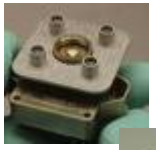
Scan Mechanism with Sun Visor, precision encoder (Messenger MASCS, MAVEN RS)

Collimating Mirror (MAVEN RS)

Detector Electronics (SSULI, JUNO, ALICE)

Kinematic Struts (MAVEN RS)





Solar Safety Sensor (MAVEN RS)

Alignment Cube (AIM CIPS, MAVEN RS)

Telescope Slit Mech Aperture (SDO EVE, MAVEN RS)

Grating Yaw Mechanism (MAVEN RS, SORCE SIM)

HVPS (AIM CIPS, SOHO, MAVEN RS)

XDL MCP Detector Assembly (SSULI, JUNO, ALICE) Detector Door (SORCE SIM, TSIS SIM)

Electronics architecture (AIM CIPS, MAVEN RS)

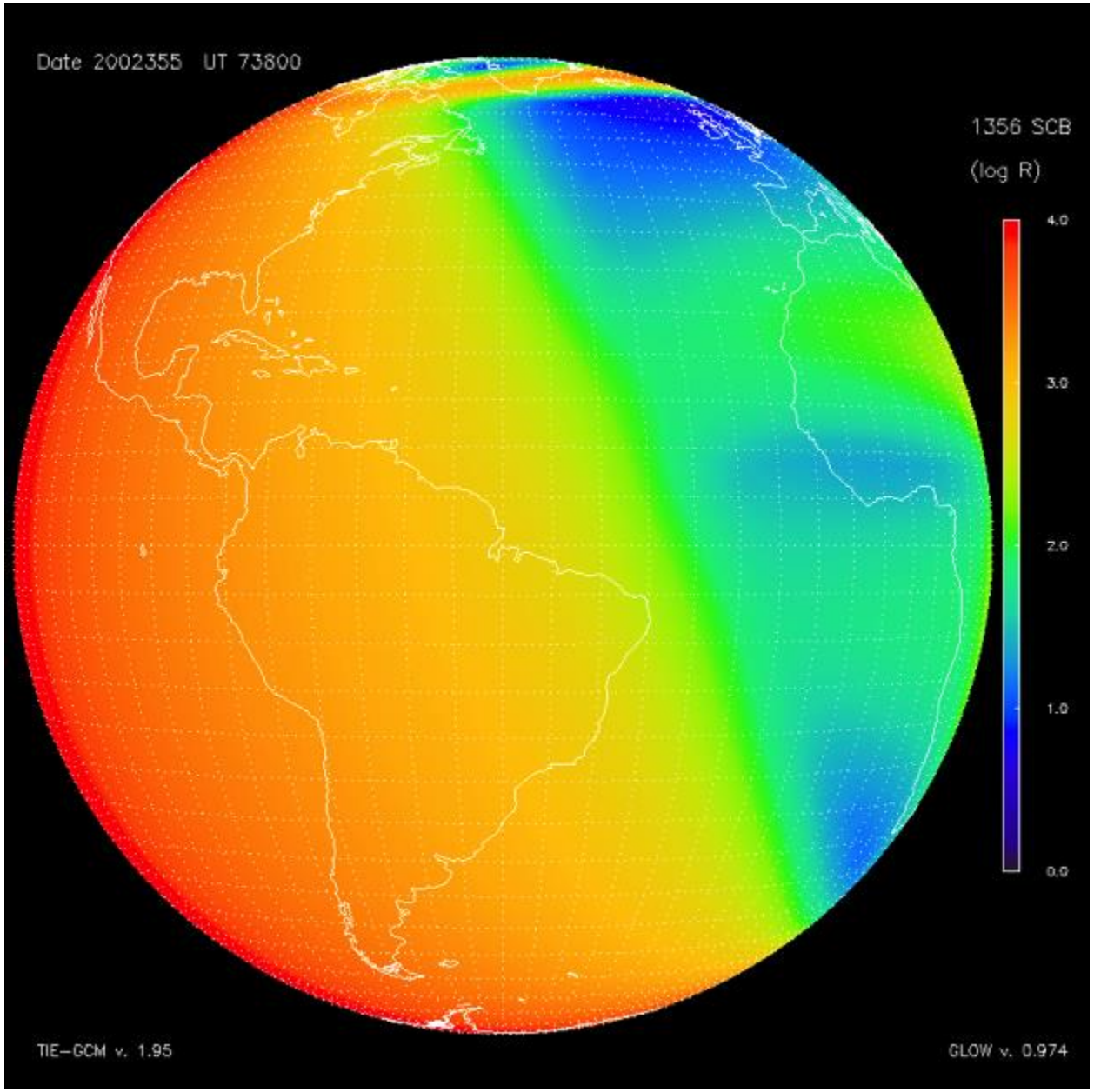
Ultraviolet Imaging from Geostationary Orbit

Simulated GOLD image of oxygen (135.6 nm) emissions

Simultaneously images N_2 emissions on dayside

Emissions provide key data for bubbles, satellite drag, and electron densities

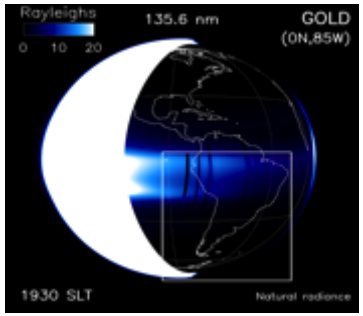
Provides data to advance predictions of assimilation models and of geomagnetic storm effects

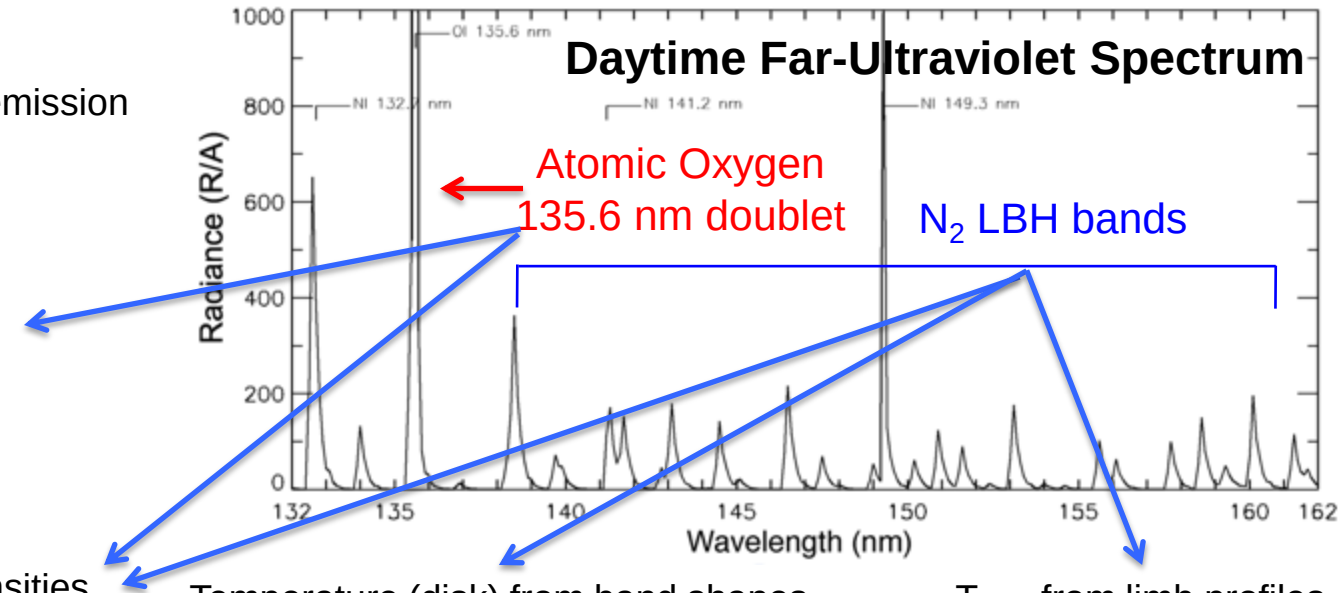


Observations Overview

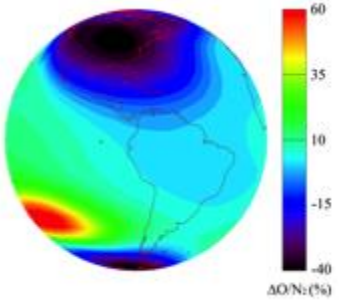
GOLD observes O 135.6 nm and N_2 Lyman-Birge-Hopfield (LBH) emissions

Nmax from O recombination emission

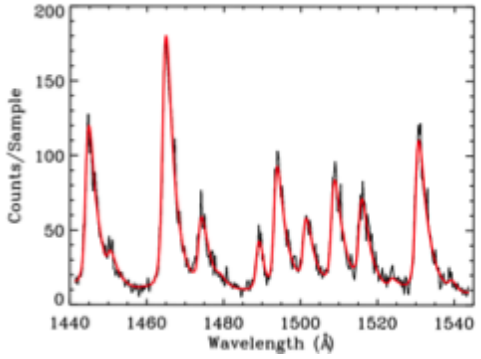




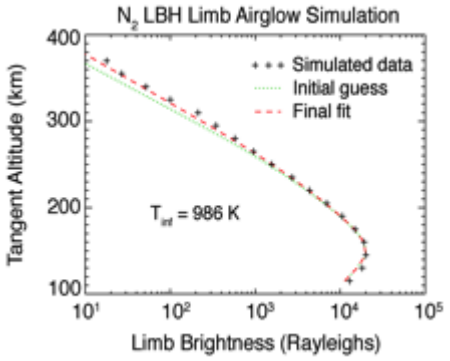
O/N_2 composition from intensities



Temperature (disk) from band shapes

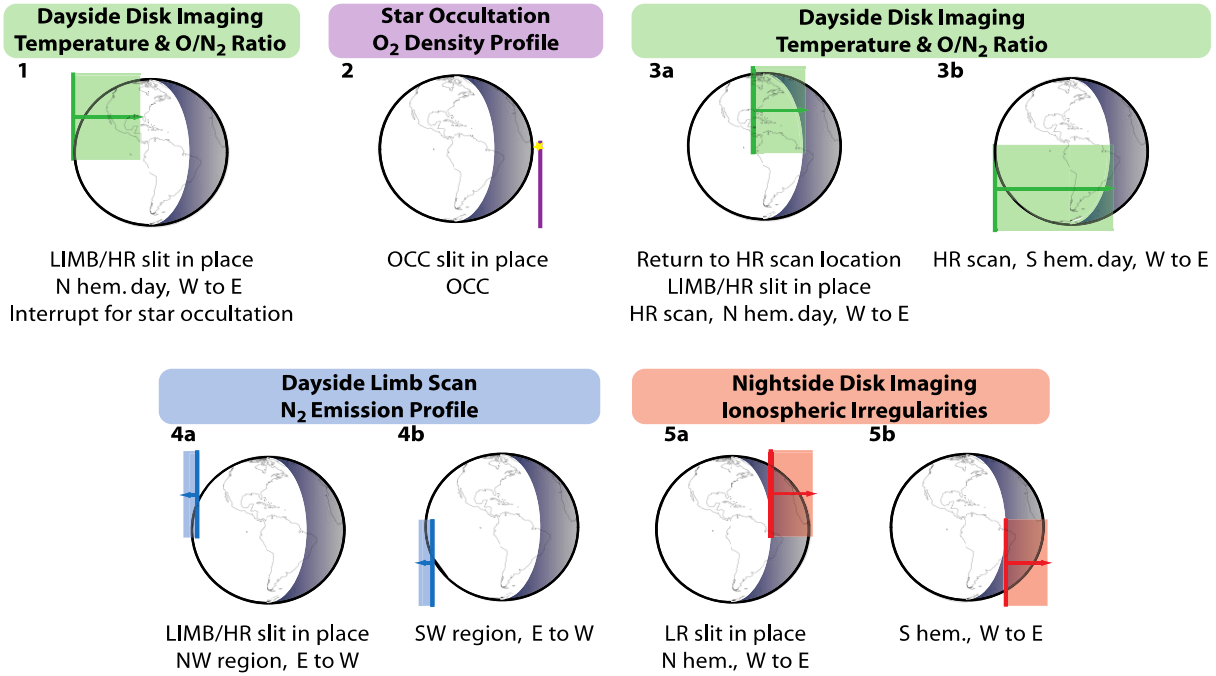


T_{EXO} from limb profiles

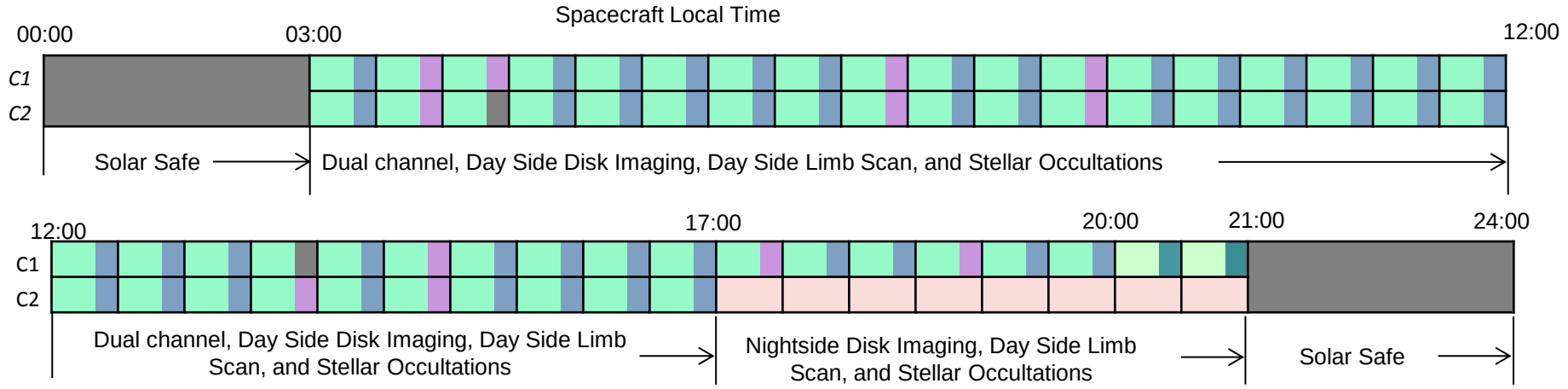


GOLD's Observing Scenario and Data Products

- **Full disk images and limb scans with 30 minute cadence**
  - **Dayside data products: Disk Temperature, Disk O/N_2, OI and N_2 emission brightness, T_{EXO}, Q_{EUV}**
  - **Nightside products: Disk OI brightness, crest locations, N_{max}**
- **Occultation measurements**
  - **Dayside and nightside products: O_2 density profile**



Concept for Observing Operations



Legend

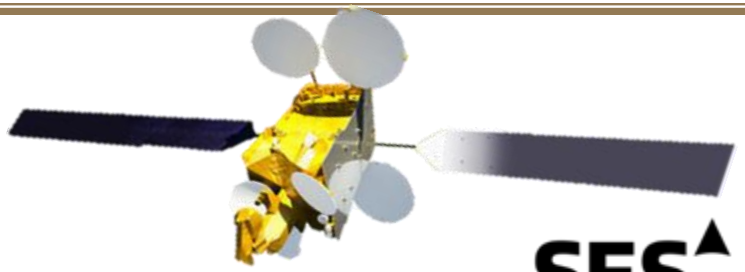
	Daily Measurements	
	Channel 1	Channel 2
Dayside Disk Image	34	28
Dayside Limb Scan	26	22
Stellar Occultation	7	5
Nightside Disk Imaging	1	4

Observation Parameters
Entrance slit
Start position — Scan rate
Step size — Scan duration

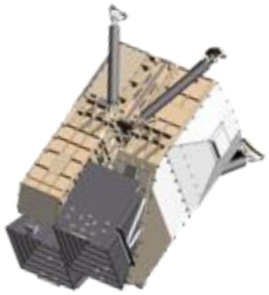
- **Nominal GOLD observing modes:**
  - **Full disk maps and limb scans with 30 minute cadence**
    - **HR: Dayside (Disk Temperature, Disk O/N_2, O and N_2 limb emission)**
    - **LR: Nightside (Disk O emissions)**
    - **HR both limbs for two hours centered on local noon**
    - **Switch between HR and LR at the terminator**
  - **O_2 occultation measurements**
    - **OCC: Dayside and Nightside**
    - **Interrupt nominal disk scans (5% duty cycle)**

GOLD Mission Space Segment

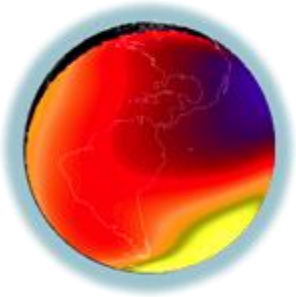
- Host Mission
  - Managed by SES
  - Host Accommodation will be on SES-14
    - GEO commercial communications satellite at 47.5° W, owned and operated by SES
    - Host satellite is a Eurostar 3000 built by Airbus Defence & Space
- GOLD Mission Instrument
  - Hosted Payload is an ultraviolet imager developed by UCF/LASP
  - 6 Mbit/s data down-link



SES Government Solutions



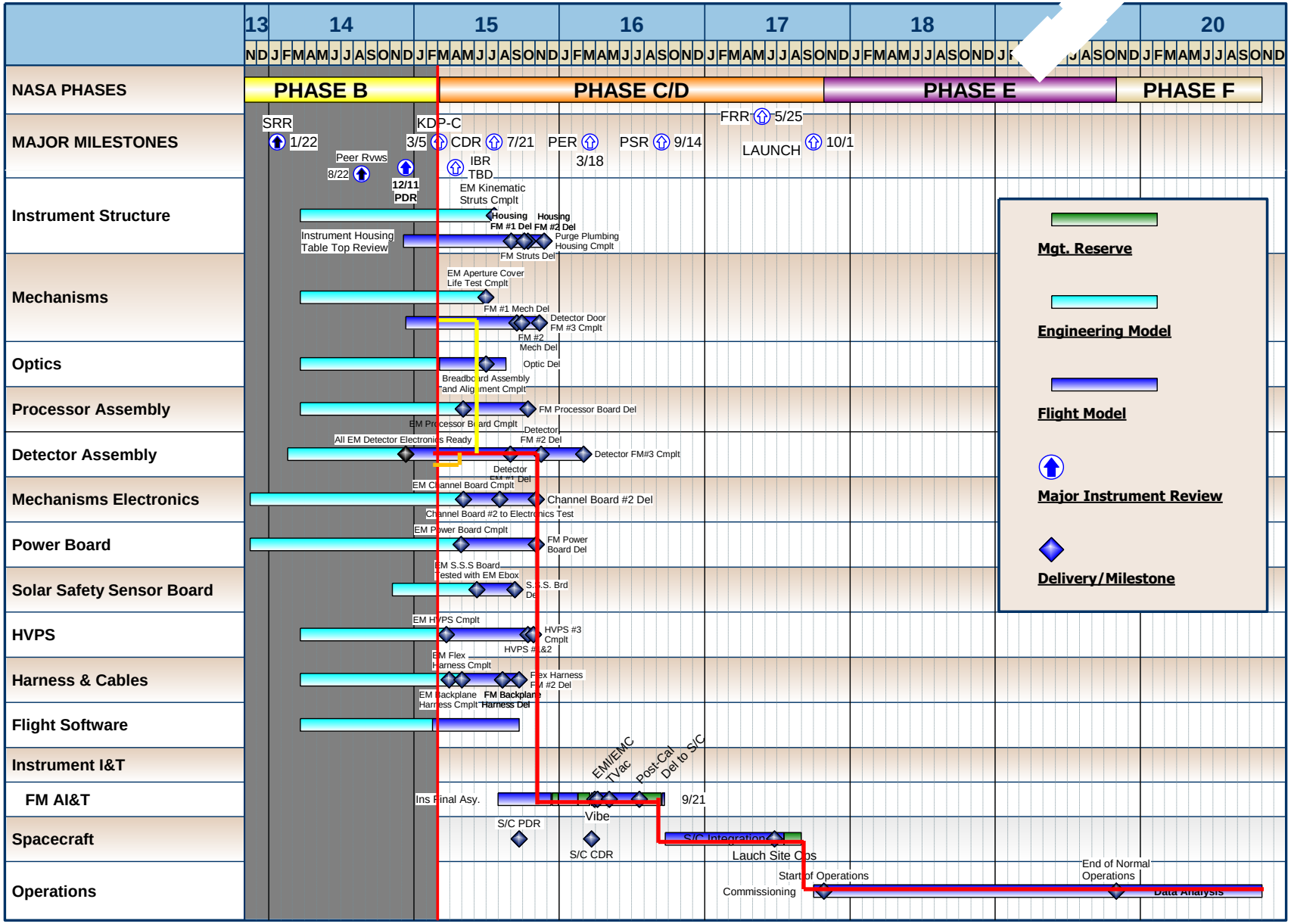
LASP



UCF

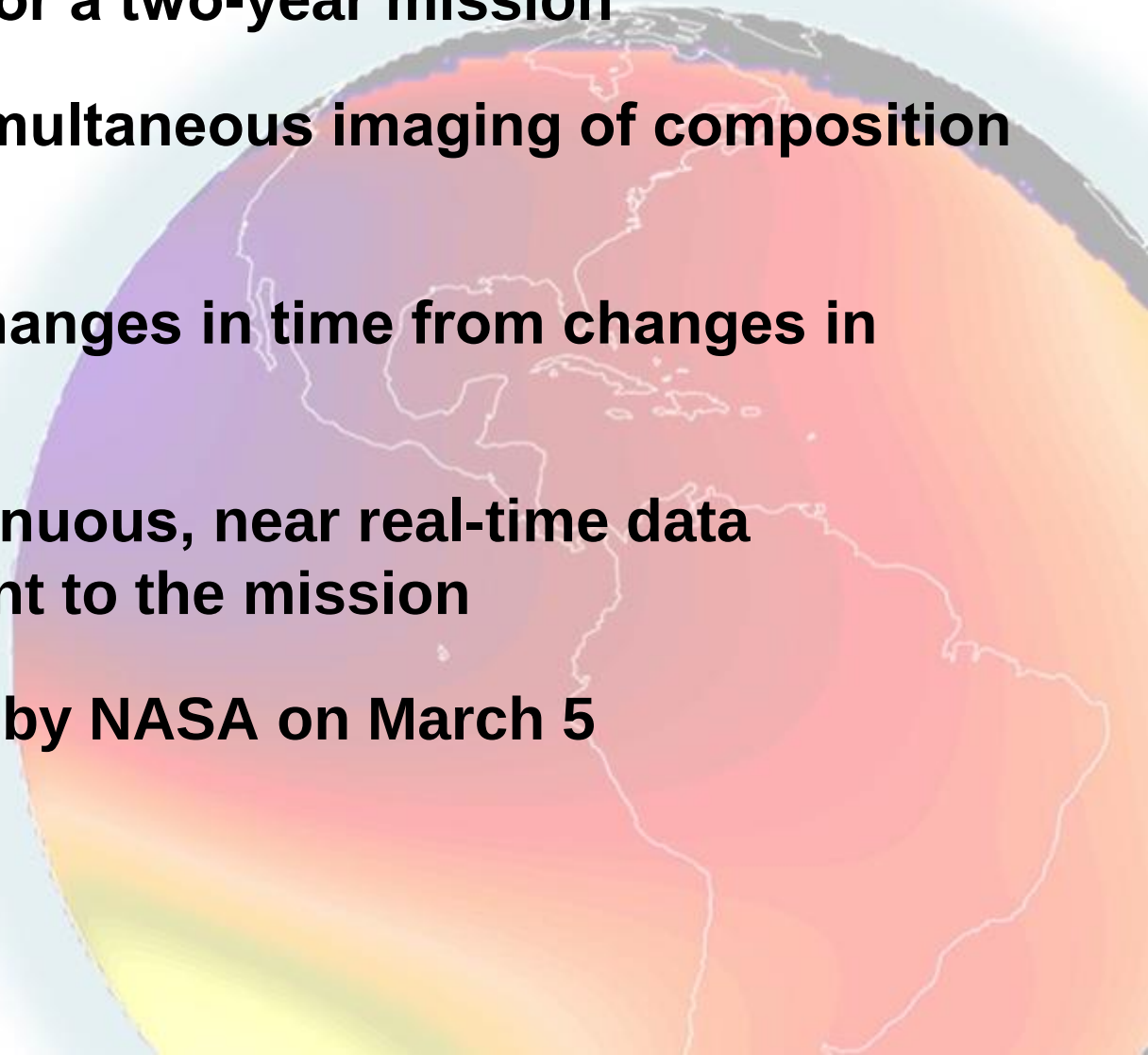
GOLD Project Schedule

2/28/15



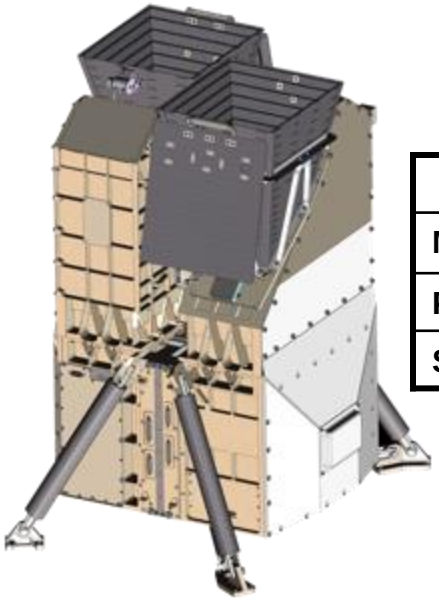
GOLD Mission Summary & Status

- Launches in 2017 for a two-year mission
- Unprecedented, simultaneous imaging of composition and temperature
- Able to separate changes in time from changes in location
- Capability for continuous, near real-time data availability is inherent to the mission
- Mission confirmed by NASA on March 5



Other

Global-scale Observations of the Limb and Disk



Instrument Summary	
Mass	33 kg (CBE)
Power	51 W (CBE, AVG)
Size	51 × 55 × 69 cm^3

Imaging Spectrograph:

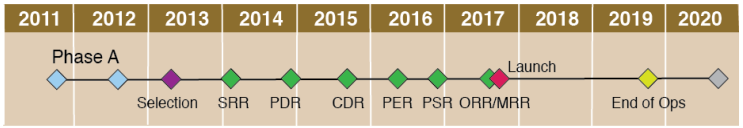
Two independent, identical channels

Wavelength range: 132 – 160 nm

Detectors: Microchannel plate, 2-D crossed delay line anode

Launch: Q4 2017

Hosted Payload on geostationary commercial satellite



Observations:

- Disk maps of neutral temperature
- Disk maps of O/N_2 density ratio
- Limb scans (for temperature)
- Disk maps of peak electron density
- Stellar occultations

Mission:

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